MODIS Total Precipitable Water

Product Description

The MODIS Precipitable Water Product (MOD 05) consists of column water vapor amounts. During the daytime, a near-infrared algorithm is applied over clear land areas of the globe and above clouds over both land and ocean. Over clear ocean areas, water vapor estimates are provided over the extended glint area. An infrared algorithm for deriving atmospheric profiles is also applied both day and night for Level 2.

Both daily Level 2 (MOD 05) and daily, 8-day, and monthly Level 3 (MOD 08) gridded averages are included. The Level 2 data are generated at the 1-km spatial resolution of the MODIS instrument using the near-infrared algorithm during the day, and at 5×5 1-km pixel resolution both day and night using the infrared algorithm when at least 9 FOVs are cloud free. The infrared-derived precipitable water vapor is generated as one component of product MOD 07, and simply added to product MOD 05 for convenience. Level 3 data are computed on 0.5° latitude and longitude, equal area and equal angle grids.

The solar retrieval algorithm relies on observations of water vapor attenuation of reflected solar radiation in the near-infrared MODIS channels so that the product is produced only over areas where there is a reflective surface in the near IR.

Research & Applications

The near-infrared total column precipitable water is very sensitive to boundary layer water vapor since it is derived from attenuation of reflected solar light from the surface. This data product is essential to understand the hydrological cycle, aerosol properties, aerosol-cloud interactions, energy budget, and climate. Of particular interest is the collection of water vapor data above cirrus cloudiness, which has important applications to climate studies. MODIS will also provide finer horizontal scale atmospheric water vapor gradient estimates than are currently available from the POES.

Data Set Evolution

The solar column water vapor parameter is derived from the attenuation by water vapor of near IR solar radiation. Techniques employing ratios of water vapor absorbing channels 17, 18, and 19 with the atmospheric window channels 2 and 5 are used. The ratios remove partially the effects of variation of surface reflectance with wavelength and result in the atmospheric water vapor transmittances. The column water vapor amounts are derived from the transmittances based on theoretical radiative transfer calculations and using look-up table procedures. MODIS is the first space instrument to use near IR bands together with the traditional IR bands to retrieve total precipitable water. Experience in this

MOD 05, MOD 08
PRODUCT SUMMARY

Coverage:
global

Spatial/Temporal Characteristics:
varies with retrieval technique;
1 km near-infrared daylight only, and
5 km infrared day and night (Level 2),
0.5° (Level 3)/daily, 8-day, and monthly

Key Science Applications:
hydrological cycle climatology, effect on aerosol and clouds, atmospheric correction, characterization of the atmosphere

Key Geophysical Parameters:
atmospheric total column water vapor

Processing Level:
2, 3

Product Type:
standard, at-launch

Science Team Contact:
B. C. Gao, Y. Kaufman, D. Tanré,
P. Menzel

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retrieval is based on an AVIRIS instrument aboard an ER-2 aircraft. Atmospheric water vapor should be determined with an accuracy of 5-10%.

The thermal column water vapor parameter is derived by integrating the moisture profile through the atmospheric column. Other split window methods also exist. This class of techniques uses the difference in water-vapor absorption that exists between channel 31 (11 µm) and channel 32 (12 µm).

Data validation will be conducted by comparing these data with water vapor measurements from the NWS radiosonde network, from ground-based upward-looking microwave radiometers, and from a ground-based sunphotometer network. Quality control will be performed in two dimensions. The first will be comparisons of specific validation sites across as many different climatic and geographic regions as possible. The second will be a statistical analysis of the entire data set.

Suggested Reading

Gao, B.-C. and A.F.H. Goetz, 1990.

Gao, B.-C., *et al.*, 1993.

Green, R.O. and J.E. Conel, 1995.

Jedlovec, G.J., 1987.

Kaufman, Y.J. and B.-C. Gao, 1992.

King, M.D., *et al.*, 1992.

Kleepsies, T.J. and L.M. McMillan, 1984.

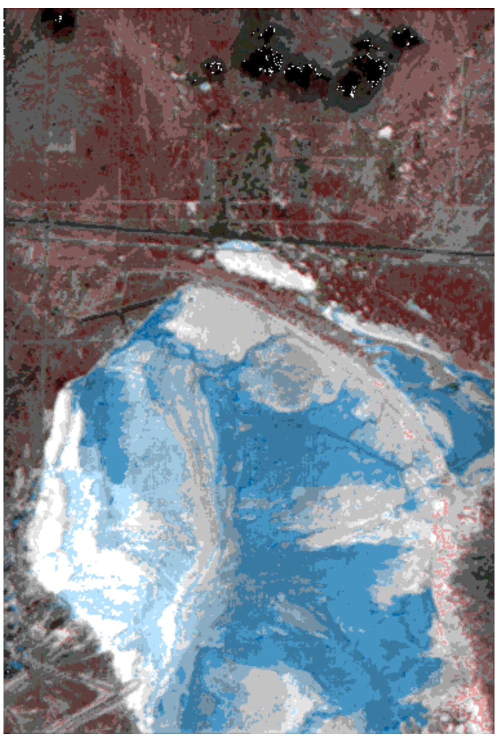

Figure 16. **Total Precipitable Water** (Green and Conel, 1995). The figure on the left represents an AVIRIS false color image of Rogers Dry Lake, California, while the figure on the right corresponds to derived column water vapor. In the water vapor image, black represents precipitable water of 1.2 cm and white precipitable water of 1.5 cm. The spatial variability of water vapor values is up to 20% over this topographically uniform terrain, but is easily detectable from measurements of solar radiation reflected by the surface in the near-infrared spectral region.

MODIS Aerosol Product

Product Description

The MODIS Aerosol Product (MOD 04) monitors the ambient aerosol optical thickness and size distribution globally over the oceans and the moist parts of the continents. The size distribution is derived only over the oceans; the aerosol type is derived over the continents. Daily Level 2 and daily, 8-day, and monthly Level 3 gridded averages are provided. The Level 2 (MOD 04) data are produced at the spatial resolution of a 10 × 10 1-km (at nadir) pixel array. The Level 3 (MOD 08) spatial resolution is 0.5° latitude and longitude, equal area and equal angle for both ocean and land, and includes not only aerosol but also cloud and water vapor properties.

Research & Applications

Aerosols are one of the greatest sources of uncertainty in climate modeling. Aerosols modify cloud microphysics by acting as CCN, and as a result impact cloud radiative properties and climate. Aerosol scatters back to space and absorbs solar radiation. The MODIS aerosol product will be used to study aerosol climatology, sources and sinks of specific aerosol types (e.g., sulfates and biomass burning aerosol), interaction of aerosols with clouds, and atmospheric corrections of remotely sensed surface reflectance over the land.

Data Set Evolution

Present satellite measurements are limited to reflectance measurements in one (GOES, METEOSAT) or two (AVHRR) channels. There has been no real attempt to retrieve aerosol content over land on a global scale. Algorithms have been developed for use only over dark vegetation. The blue channel on MODIS, not present on AVHRR, offers the possibility to extend the derivation of optical thickness over land to additional surfaces. The algorithms will use MODIS bands 1 through 7 and 22, and require prior cloud screening using MODIS data. Over the land, the dynamic aerosol models will be derived from ground-based sky measurements and used in the net retrieval process.

Over the ocean, 3 parameters that describe the aerosol loading and size distribution will be retrieved. Pre-assumptions on the general structure of the size distribution are required in the inversion of MODIS data and the volume size distribution will be described with two log-normal modes: a single mode to describe the accumulation mode particles (radius < 0.5 μm) and a single coarse mode to describe dust and/or salt particles (radius > 1.0 μm). The aerosol parameters we therefore expect to retrieve are: the ratio between the two modes, the spectral optical thickness, and the mean particle size of the each mode.

The quality control of these products will be based on comparison with ground stations and climatology.

MOD 04, MOD 08
PRODUCT SUMMARY

Coverage:
global over oceans, nearly global over land

Spatial/Temporal Characteristics:
10 km for Level 2; 0.5° latitude and longitude, equal area and equal angle (Level 3)/daily, 8-day, and monthly

Key Science Applications:
aerosol climatology, biomass burning aerosols, atmospheric corrections, cloud radiative properties, climate modeling

Key Geophysical Parameters:
atmospheric aerosol optical depth (global) and aerosol size distribution (oceans)

Processing Level:
2, 3

Product Type:
standard, at-launch

Science Team Contact:
Y. Kaufman, D. Tanré

MODIS Aerosol Product

Suggested Reading

Holben, B.N., *et al.*, 1992.

Kaufman, Y.J. and L.A. Remer, 1994.

Kaufman, Y.J. and B.N. Holben, 1996.

Kaufman, Y.J. *et al*., 1996.

Kaufman, Y.J. and C. Sendra, 1988.

King, M.D., *et al.*, 1992.

Rao, C.R.N., *et al.*, 1989.

Remer, L.A. *et al.*, 1996.

Tanré, D. et al., 1996.

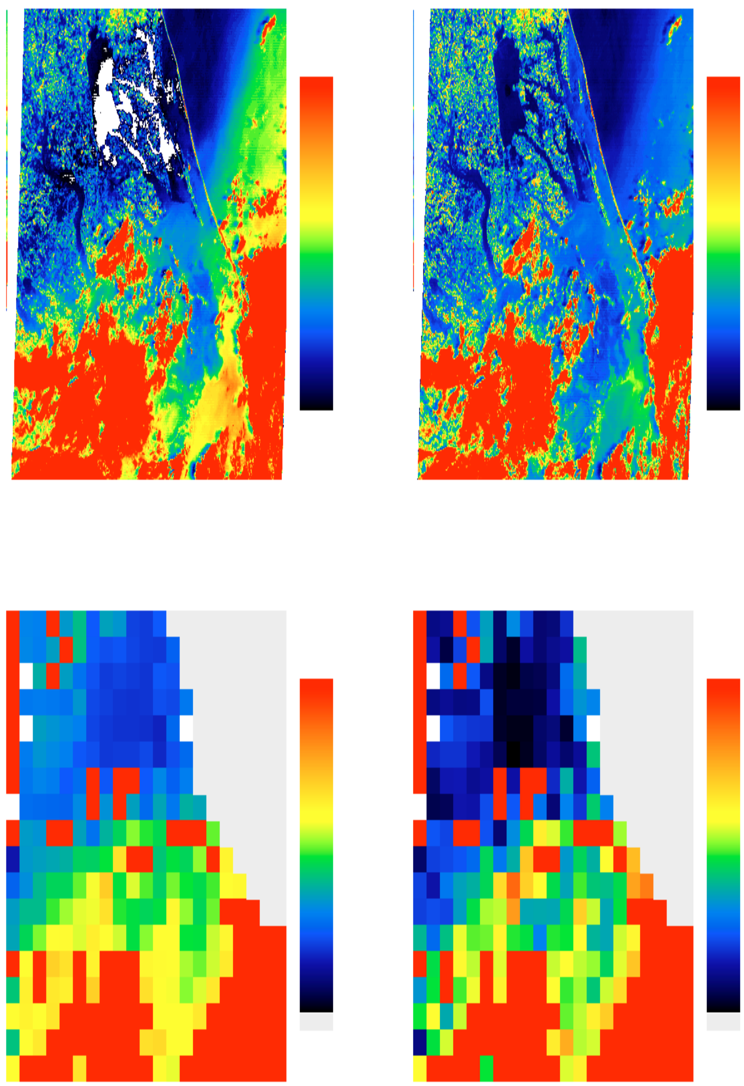

Figure 17. **Aerosol Optical Thickness.** False color Landsat TM image over the North Carolina -Virginia region (12 July 1993). The apparent reflectance of TM 0.47 µm (left) and 0.66 µm channels (right) are shown in the upper panels. The bottom panels are the corresponding aerosol optical thickness retrieved by the MODIS aerosol algorithm for the reduced resolution Landsat image.

MODIS Cloud Product

Product Description

The MODIS Cloud Product (MOD 06) combines infrared and visible techniques to determine both physical and radiative cloud properties. Daily global Level 2 (MOD06) and daily, 8-day and monthly Level 3 products (MOD08) are provided. Cloud particle phase (ice vs. water, clouds vs. snow), effective cloud particle radius, and cloud optical thickness are derived using the MODIS visible and near-infrared channel radiances. An indication of cloud shadows affecting the scene is also provided. Cloud top temperature, height, effective emissivity, phase (ice vs. water, opaque vs. non-opaque), and cloud fraction are produced by the infrared retrieval methods both day and night at 5×5 1-km pixel resolution.

Research & Applications

A thorough description of global cloudiness and its associated properties is essential to the MODIS mission for two reasons. First, clouds play a critical role in the radiative balance of the Earth, and must be accurately described in order to accurately assess climate and potential climate change. In addition, the presence or absence of cloudiness must be accurately determined in order to properly retrieve many atmospheric and surface parameters. For many of these retrievals, cloud cover, even thin cirrus, represents contamination. Key radiative properties of clouds such as phase, optical depth, and temperature may be retrieved using MODIS instruments with unprecedented resolution.

Data Set Evolution

The determination of cloud top properties will require the use of MODIS bands 29 and 31-36, along with the cloud mask product (MOD 35), to screen for clouds. In addition, NCEP or DAO global model analyses of surface temperature and pressure, profiles of temperature and moisture, and blended SST analyses will be required in the calculation of cloud forcing as a function of atmospheric pressure and emissivity. The Menzel cloud phase algorithm will require MODIS bands 29, 31, and 32 and analyses of surface emissivity.

The validation of cloud top heights will be conducted through comparisons with stereo determinations of cloud heights from GOES and lidar estimates and aircraft observations of cirrus heights. Cloud emissivity will be compared to lidar determined values. These interim products will be used in concert with field campaigns with the MAS instrument. The Menzel cloud phase parameter will be validated using HIRS/AVHRR data and by comparison to the King cloud phase parameter.

The King cloud phase algorithm requires product MOD 02, calibrated multispectral radiances. Cloud particle size and optical depth require these radiances plus the cloud top parameters within MOD 06 and

MOD 06, MOD 08
PRODUCT SUMMARY

Coverage:
global

Spatial/Temporal Characteristics:
varies with parameter; once or twice per day, at resolutions of 1 km or 5 km (Level 2) and 0.5° latitude and longitude, equal area and equal angle (Level 3)/ daily, 8-day, and monthly

Key Science Applications:
cloud parameterization, climate modeling, climate monitoring, increasing accuracy of other MODIS retrievals

Key Geophysical Parameters:
cloud particle phase (two algorithms), cloud particle size and optical depth, and cloud top temperature, emissivity and height

Processing Level:
2, 3

Product Type:
standard, at-launch

Science Team Contact:
P. Menzel, M. King

MODIS Cloud Product

the Menzel cloud phase parameter. In addition, these parameters require MODIS product MOD 09 (surface reflectance) and the NCEP analyses and profiles described above. The validation and quality control of these products will be performed primarily through the use of *in situ* measurements obtained during field campaigns and with the use of the MAS instrument.

Suggested Reading

King, M.D., *et al.*, 1992.

King, M.D., *et al* ., 1996.

Nakajima, T.Y. and T. Nakajima, 1994.

Platnick, S., *et al* ., 1996.

Strabala, K.I., *et al.*, 1994.

Wylie, D.P., *et al.*, 1994.

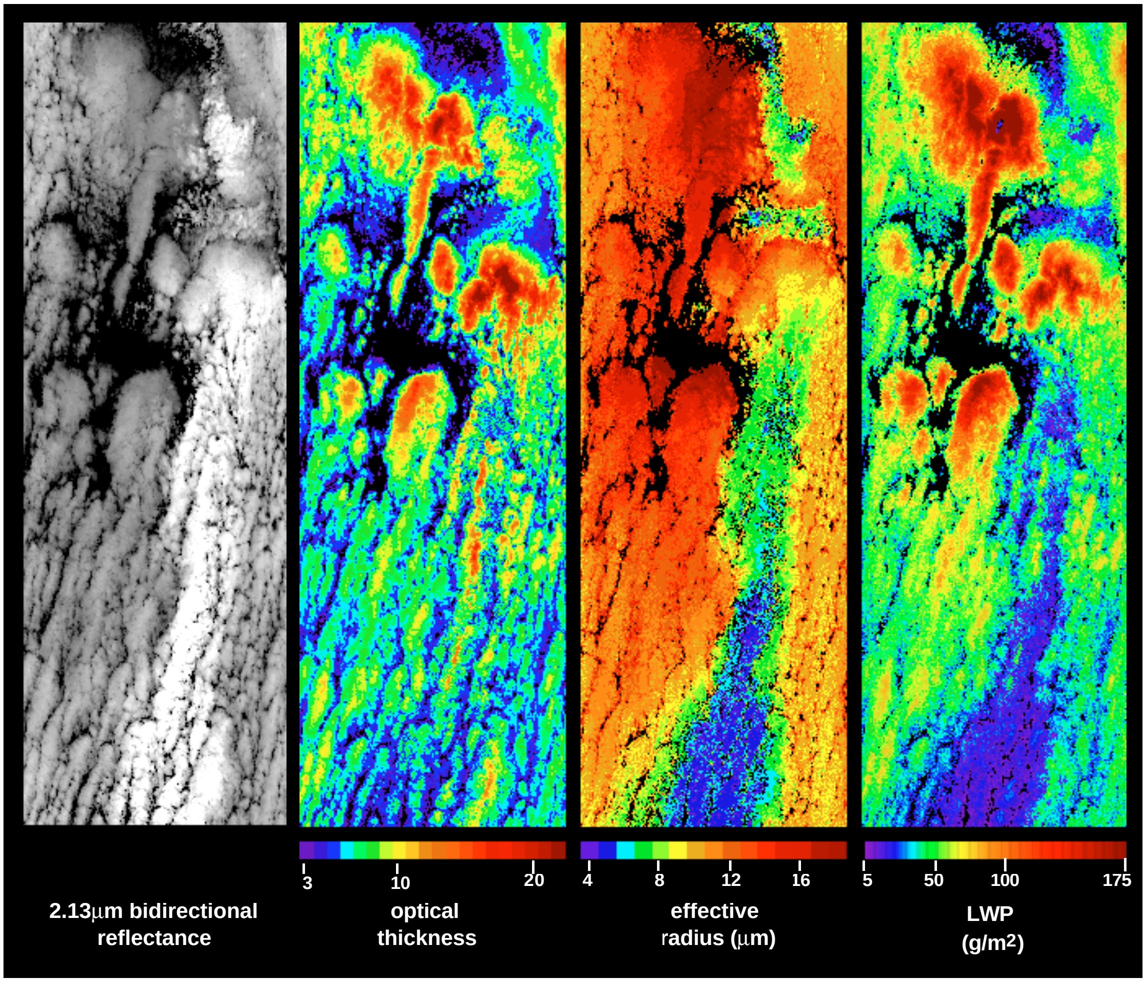

Figure 18. **Cloud Optical Thickness and Effective Radius**. MODIS Airborne Simulator 2.13 µm bidirectional reflectance along with retrieved cloud optical thickness, effective radius, and liquid water path (using MAS visible and 2.13 µm channels) for the southern portion of a ship track imaged off the coast of California on 29 June 1994. The ship is easily seen as the bright region in the reflectance panel and as the lower droplet size in the effective radius panel; the track is not obvious in the optical thickness panel. The last panel is liquid water path which is approximated as being proportional to the product of optical thickness and effective radius.

MODIS Cloud Product

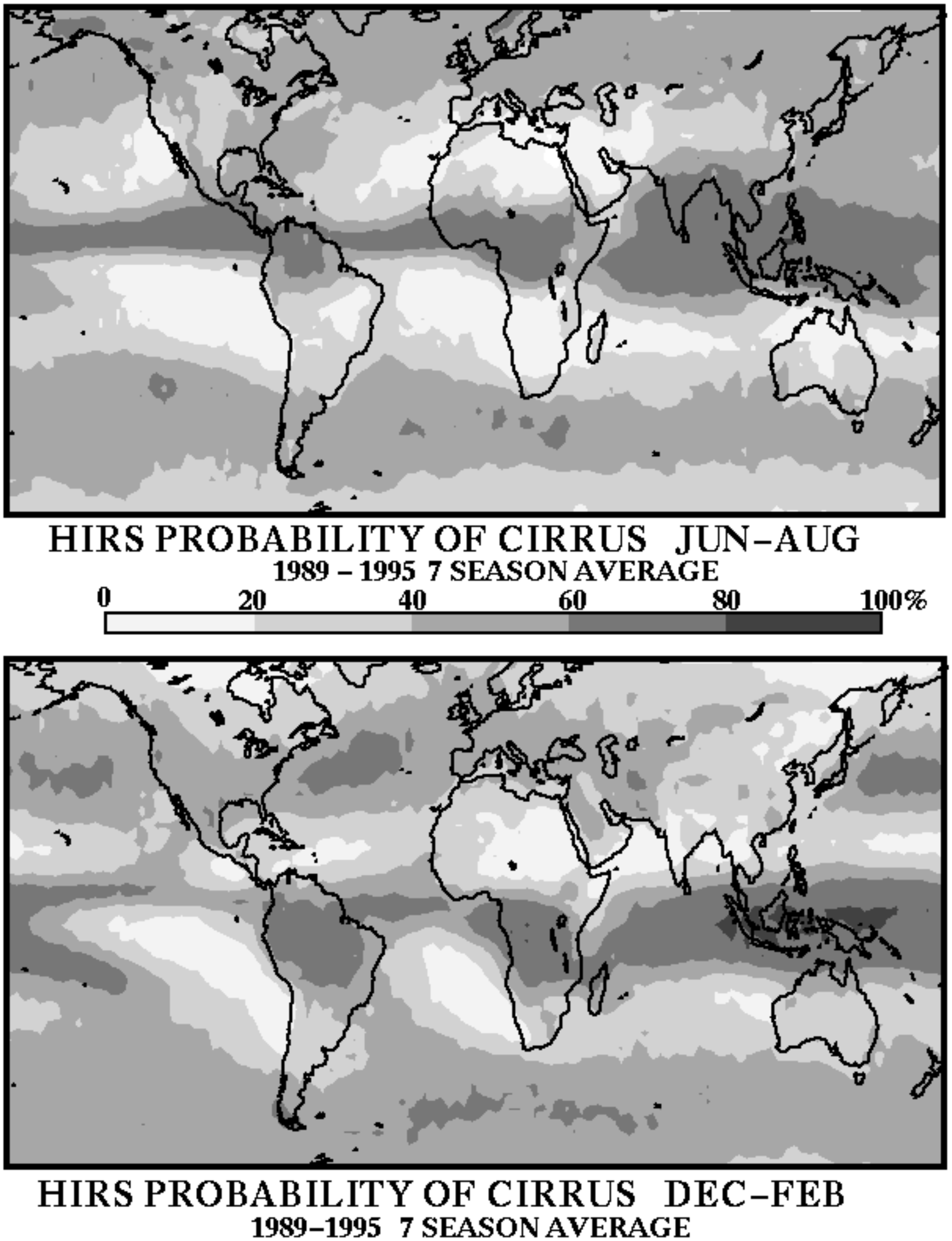

Figure 19. **HIRS Probability of cirrus**. Level 3 MODIS cloud product using a combination of the effective emissivity and cloud top pressure product to determine a geographical distribution of cirrus cloud. HIRS observations were used to generate this example. Top figure is for June-August, and the bottom figure December-February. Both panels represent 7 year averages.